BREEDING BEHAVIOUR OF THE BLACK-NECKED STORK *EPHIPPIORHYNCHUS ASIATICUS* IN DUDHWA NATIONAL PARK, INDIA[1]

GOPINATHAN MAHESWARAN[2] AND ASAD R. RAHMANI[3]

[1]Accepted
[2]Department of Wildlife Sciences, Aligarh Muslim University, Aligarh 202 002, Uttar Pradesh, India.
Present Address: Zoological Survey of India, M-Block, New Alipore, Kolkata 700 053, West Bengal, India.
Email: gmaheswaran@yahoo.com
[3]Bombay Natural History Society, Hornbill House, S.B. Singh Road, Mumbai 400 023, Maharashtra, India.
Email: bnhs@bom3.vsnl.net.in

The breeding behaviour of the Black-necked Stork (BNS) (*Ephippiorhynchus asiaticus*) was studied from mid-September 1996 to mid-January 1997 in Dudhwa National Park (DNP). Observations were made for 749 hours on a single pair of breeding BNS. Both the sexes were engaged in gathering a variety of nest material. Nest material was collected throughout the breeding season, till the juveniles left the nest; dried grasses were collected most (69%) for nest insulation. The parental investment of male and female BNS was not equal. The pair spent almost 15% of its time incubating/resting and this varied significantly in various chick stages. Time spent on this activity was more during the early part of the day. Male and female spent almost equal time feeding their juveniles throughout the breeding season, whereas the frequency of feeding trips between the sexes varied significantly. As the chicks grew, there were changes in the type and amount of food delivered to the chicks. The breeding pair was very aggressive towards conspecifics, mainly to safeguard its nest and the nearby feeding grounds. Unusual competitions were recorded between adult male and female BNS for food on the nest; when one of the parents tried to feed the young, the partner tried to pilfer it. The parents brought water generally during mid-day, than in the morning or evening. Since nothing was known about the breeding behaviour of BNS, this work has revealed much, especially about the parental care and development of young.

Key words: Black-necked Stork, *Ephippiorhynchus asiaticus*, nest site selection, nest materials, breeding, parental investment

INTRODUCTION

The Black-necked Stork (*Ephippiorhynchus asiaticus*) was once widespread throughout south-east Asia and Australia; it has more recently declined in, or been extirpated from most of its world range (Kahn 1987). It has declined steadily in the Indian subcontinent (Rahmani 1989; Maheswaran *et al.* 2004). The Black-necked Storks of tropical Asia and Australia are uncommon throughout most of their range. This species currently ranges from India, Sri Lanka to Australia. In many places, however, populations have reached critically low levels (Dorfman *et al.* 2001). It is a solitary breeder and probably mates with the same partner during successive seasons. Pairs are frequently seen together even outside the breeding season (Kahl 1971). It is a very late breeder in India, starting in September in northern India that coincides with the end of the monsoon and in late November to early December elsewhere (Baker 1938). Except Kahl's (1971) brief study on the breeding biology of this species near Bharatpur, Rajasthan in 1966-67, no major study was undertaken before our study in Dudhwa National Park.

Information on activity pattern (Maheswaran 1998), effects of wading bird abundance on the foraging behaviour (Maheswaran and Rahmani 2001), and foraging behaviour and feeding success (Maheswaran and Rahmani 2002) of the Black-necked Stork are known. However, breeding behaviour, especially parental care of juveniles, is not known. Sundar's (2003) paper on the post-fledgling breeding success and productivity of the Black-necked Stork in an unprotected area of Uttar Pradesh is noteworthy. In 1996-97, out of three pairs, one pair of BNS was observed breeding within the Park. Here we document the breeding behaviour of this pair of adult Black-necked Storks and the type of food offered to the juveniles by the parent birds.

METHODS

Study area: Dudhwa National Park (DNP) is situated on the Indo-Nepal border in the Nighasan *tehsil* of Lakhimpur-Kheri district in Uttar Pradesh, within the *Terai*-bhabar biogeographic subdivision of the upper Gangetic Plain (Rodgers and Panwar 1988). The Park (*c.* 614 sq. km) lies between 28° 18' - 28° 42' N and 80° 28' - 80° 57' E. The Himalayan foothills are about 30 km north of the Park, and the rivers Suheli and Mohana form the natural boundaries of the Park. If the monsoon water level were to decrease, prey would become concentrated in the wetlands. The Forest Department therefore pumps water into the wetlands to maintain the water level primarily for the endangered Swamp Deer (*Recervus duvauceli*), which also benefits the BNS. As

pumped in water is available even during peak summer it maintains the territory and food supply of the BNS. The decreasing water level would have forced most birds to abandon the wetlands. Eight to ten hours supply of water for 10-15 days compensates water loss due to evaporation, facilitating birds such as BNS, egrets and herons. We located a solitary nest of the Black-necked Stork on September 20, 1996 in Kheima-Gauri area of Bankatti Range in Dudhwa National Park, Uttar Pradesh, India. The nest was on a Kheima or Haldu (*Adina cordifolia*) tree at a height of *c.* 20 m. No other tree was present within a radius of 25 m. Tall and short grasses, including *Saccharum munja*, *Imperata cylindrica* and *Desmostachys bipinnata*, surrounded the nesting tree.

Behavioural observations: Since no permission was given to build a hide close to the nest tree, all the observations were made from a hide on the nearest tall tree (23 m) 17 m above the ground. The distance between the hide and the nest tree was 80 m. Observations were made through a spotting scope and disturbance due to the observer was minimal, except when entering the hide. Once we entered the hide, the adult birds remained undisturbed. The nest being almost level with the hide, we could see the type of food the parents offered to the juveniles and sometimes even the exact number of whole fish. Most of the nests of the Black-necked Storks in India were located at 6-25 m above the ground, in trees such as Kadamb (*Acanthocephalus kadamba*), Peepul (*Ficus religiosa*), and Simul (*Bombax malabarica*) (Kahl 1973). The nest which we studied intensively (from September 20, 1996 to January 13, 1997; 116 days) was 120 m from the nearest human habitation (forest post on Indian side) and 140 m from agricultural fields in Nepal, and the breeding pair was habituated to human presence. Observations were made daily from 0600 to 1800 hrs. Observations were not made at night. Data were collected only from mid-September 1996 and the actual egg laying dates were not known, as the adult birds were already on the nest when we reached the site; probably they occupied the old (Hancock *et al.* 1992) nest built by them in the previous year. The nest was *c.* 1.5 m in width, placed on top of a tall tree at a point from which three barren stumps emerged. Eggs and chicks were not measured.

The behaviour of nesting BNS were broadly classified into 13 categories (Kahl 1973). Activities of both the male (having dark brown iris) and the female (having dark yellow iris) were recorded simultaneously when both were on the nest together. Focal animal sampling was used to record the activities, but two different sets of data sheets were used to record activities separately whenever both birds were on the nest. Whenever an adult stork brought any nest materials (mainly for lining or insulation), the type and quantity were recorded, and we termed such trips as the 'Nest Material Trip'. We term 'Wet Grass' as dried grasses soaked in water or drenched in dew brought to the nest by adult storks. Adult storks mostly collected 'Dry Grass' during mid-day. In addition, the time of each nest material trip, weather conditions and the time taken to insert the nest material were also recorded. When the parent storks poured water ('Watering Trip') on the chicks, the amount (less when water-drops dripped and more when water was poured from the bill) and number of drools were also recorded. In case of 'Feeding Trips', the amount (based on the number of full fish and their approximate length compared with bill length of stork) and type (anything other than fish) of food was observed.

Time duration for each activity was recorded with a stop-watch and the percentage of time spent on each activity was calculated with respect to chick stages (Chick Stage 1 (CS1) = 0-10 days old, CS2 = 11-20 days old; CS3 = 21-30 days old, CS4 = 31-40 days old, CS5 = 41-50 days old, CS6 = >51 days old) and the time of day. For our convenience and data analysis, we divided the number of days juveniles were present on the nest into six different chick stages, each spanning ten days; we presume that this does not have any ecological significance. All the percent values were arc-sine transformed, and only on such data were statistical tests performed. The Kruskal-Wallis test was used to determine the time an adult BNS spent on each activity in different months and at different chick stages, and Mann-Whitney U test was used to determine how each activity differed between sexes in different months and chick stages. Statistical packages STATA 5.0 (StataCorp 1997) and SPSS 6.1 (Norusis 1994) were used for data analysis.

RESULTS

Incubation and resting: Adult storks on the nest were observed for 85 days, covering 354 hrs for male and 395 hrs for the female. Both male and female BNS incubated, but the female spent more than 50% of its time for incubation, especially in September 1996 (Table 1). Clutch size was unknown, but three chicks were present in the nest. The first chick probably hatched on October 17, 1996. This was confirmed when parent birds started bringing fish many times during a day from October 19. One chick 10-15 day old died due to unknown reasons; it was later cannibalised (passive) by the adult male. Only 25% of the adults' time was spent incubating the eggs.

Standing and brooding in different chick stages: The pair spent 15% of its time resting and brooding the young and this varied significantly in different chick stages (χ^2=65.055, d.f. 5, P<0.01; Table 2). From September till mid-October adult storks spent almost 50% of their time away

from the nest. Twenty-five percent of the time was spent guarding the nest, by standing at the rim of the nest. The male BNS spent 13.6% of his time in resting; the resting time varied significantly in different chick stages (χ^2=41.309, d.f. 5, P<0.01). Time spent resting was more during the early part of the day, this could be to keep the juveniles warm, when the temperature is as low as 6 °C in December.

The female BNS spent about 17% of her time brooding and resting, which varied significantly in various chick stages (χ^2=25.269, d.f. 5, P<0.01; Table 2). Time spent on this activity was most during 1400-1800 hrs (Table 3). The female spent more time for resting than the male (Z=2.054, P<0.04) during the different chick-stages.

Nesting materials: Both male and female storks left the nest frequently to collect nest materials, but at least one of the parent remained on the nest until all the juveniles became independent. Often parents returned with only nest materials (Table 4), on a few occasions (n=5), however, food and water was brought with the nest material. Both sexes were observed engaged in nest material gathering and placement of collected materials independently, however, on two occasions they were seen arranging the nest material together.

The storks spent 10.4% of their time to bring nest materials, which included dry twigs, grasses, green leaves/ plants, cloth and polythene scrap. Rarely did they bring any greenery, and if so only the green veins of *Telliacora acuminata* (which normally do not have much leaves), besides small branches of other unidentified green plants. The Black-necked Storks mostly used dry grasses (Table 4) composed within a radius of 100-300 m for nest insulation. The frequency of nest material trips varied greatly during different times of the day (Table 5).

Feeding the chicks: As the chicks (n=2) grew, they adopted begging posture; the begging calls were clearly audible at a distance of 80 m. The hungry juveniles raised begging calls immediately after the parents arrived at the nest. When the chicks grew bigger they consumed more food, this

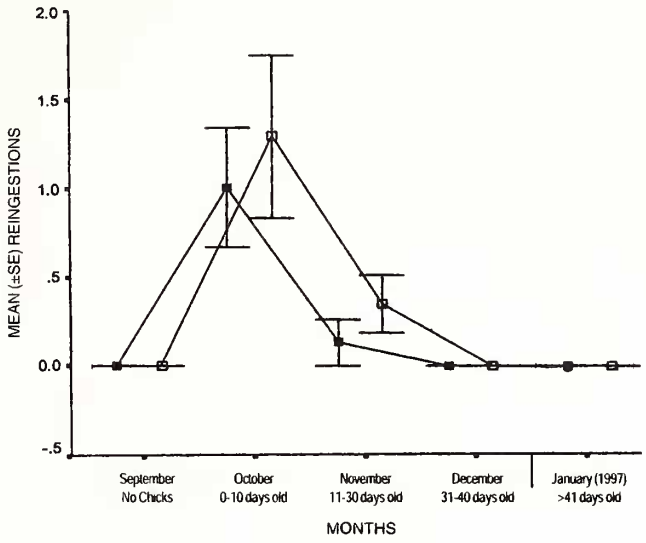

Fig. 1: Number of reingestion trips made by male (empty square) and female (solid square) Black-necked Stork in different months

Table 1: Percent time spent on various activities by the male and female Black-necked Storks during the breeding season (1996-1997) in Dudhwa National Park.

Activity	September*		October		November		December		January		Overall	
	M	F	M	F	M	F	M	F	M	F	M	F
Bill clatter	0	0	0.20	0.52	0.02	0.37	0.04	0.26	0.30	1.07	0.14	0.02
Chick maintenance	0	0	9.82	2.17	0	0	0	0	0	0	6.60	0
Defecation	0	0	0.90	0	2.61	0.55	0.02	0.84	0	0	1.20	0.21
Feeding the chicks	0	0	5.40	6.93	5.38	2.83	2.57	9.17	13.6	9.97	4.39	4.60
Away from nest	51.7	0	20.9	0	26.4	4.90	40.3	3.17	41.3	0	26.6	25.3
Nest arrangement	0	0	5.21	2.78	2.33	1.84	0.28	1.33	0.26	0.21	3.61	7.15
Bringing nest material	0	0	17.8	7.31	2.67	5.64	2.54	6.25	0.75	0.47	12.0	8.71
Preening	0	0	6.74	10.6	18.5	11.8	11.6	7.27	8.86	34.8	9.39	13.7
Re-ingestion	0	0	1.51	1.74	0.03	0.51	0	0	0	0	1.02	0.34
Standing/brooding	28.1	48.8	17.0	32.6	25.8	34.9	13.4	42.4	28.5	20.7	17.24	16.7
Incubating/resting	19.8	50.6	13.7	33.8	6.76	31.4	25.8	27.9	6.28	15.0	13.6	17.1
Wing stretching	0	0	0	0	5.85	3.24	3.26	1.41	0.10	0.48	2.53	3.02
Watering	0.26	0.62	0.66	1.43	1.74	1.21	0	0	0	0	0.81	2.98
Yawning	0	0	0	0	1.78	0.76	0.08	0	0	17.2	0.68	0.04

* - September till mid October was the incubation period.
Zeros represent no time spent on that particular activity by storks. (Male = 354 h; Female 395 h of observations)

was also evident from the reduced number of re-ingestions made by adult storks recorded during the breeding season (Fig. 1) and chick stages (χ^2= 17.20, d.f. 5, P<0.04). The parents regurgitated the food they brought onto the nest floor whether or not the chicks were begging for food. The juveniles preferred to consume bigger fish, followed by smaller ones. Fish were swallowed whole without being mutilated in about 2-6 seconds, depending upon the size of the fish.

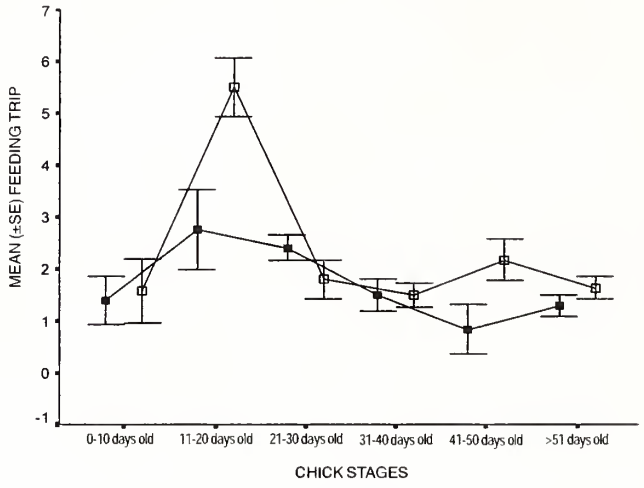

Fig. 2: Number of feeding trips made by male (empty square) and female (solid square) Black-necked Stork in different chick stages

Combined together, the pair spent 4% of its time feeding the chicks. However, the male spent 5% of its time and this differed significantly in different chick stages (χ^2=21.612, d.f. 5, P<0.01). The male fed the chicks more during the early part (0600-1000 hrs) of the day and the second peak was from 1400-1800 hrs (Table 3). The frequency of parents feeding the juveniles in different chick stages is given in Fig. 2. The female stork spent 4.6% of her time feeding the chicks, and this did not differ significantly among different chick stages. She fed the chicks most during 1000-1400 hrs (Table 3). The male fed the juveniles more and a greater number of times than the female, this was evident from the percentage time away (presumed to be foraging) from the nest, which was more for the male than female (Z= -2.012, P<0.04).

Watering: The pair under study spent about 2% of its time watering the chicks. This activity varied significantly in different chick stages (χ^2=19.095, d.f. 5, P<0.01). The frequency of watering trips by the male, in different chick stages, is given in Fig. 3. Even though the number of drools made by both the sexes was almost equal, the male poured more water over the eggs and chicks. The male stork made more watering trips during 1000-1400 hrs (Table 3), especially during September and October. The storks maintained the nest temperature at an optimum level and whenever there was an increase in the mean temperature they poured water over the

Table 2: Activities of male and female Black-necked Stork during different chick stages recorded during the breeding season in Dudhwa National park

Activities	Chick stages											
	CS1*		CS2		CS3		CS4		CS5		CS6#	
	M	F	M	F	M	F	M	F	M	F	M	F
Bill clattering	0.30	0.42	2.71	0.60	0.04	0.36	0.03	0.32	0.04	0.46	0.07	0.75
Defecation	0	0	0.06	0	5.52	0.62	0.05	0.65	0	0.47	0.02	0.86
Feeding the chicks	6.3	6.20	5.29	5.63	9.20	1.30	1.95	0.80	1.84	0.49	3.96	9.06
Away from nest	18.2	0	42.2	9.95	55.7	0	17.3	0	46.1	0	40.4	2.88
Nest arrangement	8.2	2.47	0.48	1.56	1.8	3.89	3.42	1.46	2.3	1.43	0.06	0.90
Bringing Nest material	17.8	6.15	4.85	3.56	0.23	1.97	0.93	9.90	0	9.67	0.18	18.4
Preening	6.14	7.87	10.7	19.8	1.40	11.7	8.49	11.8	31.8	3.53	11.7	6.42
Re-ingestion	2.11	1.39	1.08	1.63	0	0	0	0	0	0	0	0
Standing/guarding	14.3	27.9	16.7	38.2	11.3	53.1	44.6	40.3	11.5	29.2	13.7	35.7
Resting	9.79	29.0	15.7	16.3	1.84	24.2	12.9	32.6	6.43	46.8	26.4	23.3
Wing stretching	0	0	0.04	0.88	5.5	1.25	10.1	1.29	0	7.96	3.38	1.13
Watering	0.81	0.98	0.03	1.86	3.68	1.55	0	0	0	0	0	0
Yawning	0	0	0.05	0	3.7	0	0.10	0.87	0	0	0.08	0.64

CS1= 0-10 days old, CS2= 11-20 days old, CS3= 21-30 days old, CS4= 31-40 days old, CS5= 41-50 days old, CS6= >51 days old.

* = begins on October 20, 1996 (post-incubation period); # = Till January 13, 1997

eggs or chicks.

The female BNS spent 3% of her time watering, and this differed for different chick stages (χ^2=14.624, d.f. 5, P<0.01). The female stork made more watering trips during 1000-1400 hrs (Table 3). Time spent by the male and female BNS for watering did not differ significantly (Z=1.700, P>0.08) throughout the breeding season.

The male was seen to drool more water than the female. The Mann-Whitney U test result shows that frequency of drools did not differ significantly (Z=0.941, P>0.34), but as mentioned above, the quantity of water in each drool varied between the sexes. However, this could not be quantified for any statistical tests. On cloudy days (especially in November and December) there were no watering trips.

DISCUSSION

As a monogamous species, both sexes of Black-necked Storks should have spent almost equal amount of time (Trivers 1972) to care for their juveniles. The female spent more time for incubation and nest guarding than the male, whereas the male fed the juveniles more and made more feeding trips than the female. However, the total time spent for feeding the juveniles remained equal for both the sexes. According to Hancock and Kushlan (1984), the level of investment may be influenced by factors such as parent-offspring relatedness, age, number of chicks, condition of parent and offspring, and season.

Table 3: Percentage time spent on different activities by male (n=354 h) and the female (n=395 h) Black-necked Stork according to time of day recorded during breeding season in Dudhwa National Park

Activities	Time of day (hrs)					
	0600-1000		1000-1400		1400-1800	
	M	F	M	F	M	F
Bill clattering	0.02	0.02	0.04	0.03	0.009	0.004
Defecation	0.06	0.00	0.02	0.006	0.04	0.07
Feeding the chicks	0.97	0.48	0.25	1.60	0.36	1.15
Away from nest	55.1	68.5	34.5	52.3	64.6	44.6
Nest arrangement	0.75	0.80	1.58	0.07	0.10	0.73
Bringing nest material	2.35	1.08	0.63	1.23	0.67	1.51
Preening	4.67	4.03	3.72	4.27	3.55	4.97
Re-ingestion	0.28	0.13	0.03	0.07	0.05	0.15
Standing/guarding	20.1	14.4	48.2	26.6	22.5	31.6
Incubating/resting	15.5	9.93	10.2	13.4	7.05	14.3
Wing stretching	0.009	0.009	0.08	0.10	0.08	0.47
Watering	0.009	0.13	0.04	0.21	0.00	0.05
Yawning	0.03	0.03	0.46	0.003	0.95	0.02

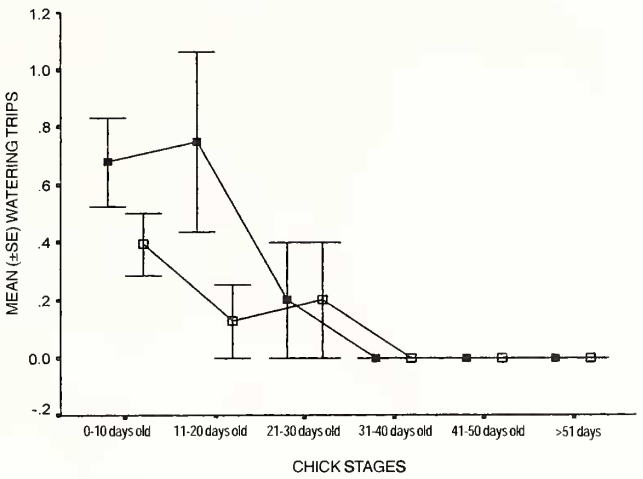

Fig. 3: Number of watering trips made by male (empty square) and female (solid square) Black-necked Stork during different chick stages

Birds may select a tree for nesting by looking at the tree structure and its proximity to feeding sites and human disturbances, so that no predator can easily access the nest. It appears that availability of food is the prime factor among breeding BNS in Dudhwa while selecting the nest site. Uninterrupted food supply from the nearby wetlands during the breeding season helps the BNS protect the nest/juveniles from predators as it can stay at the nest for longer periods. Once this is assured, the storks select the trees for the nest (Maheswaran 1998). Black-necked Storks (especially the study pair) in Dudhwa built their nest on a tall *Adina cordifolia* tree, situated amidst tall grassland habitat where no other nests of big birds were present. Large Ciconiiformes are not likely to nest in dense or low vegetation (Burger 1978).

Nest material, especially the lining, was brought separately by male and female Black-necked Storks throughout the incubation and brooding periods in DNP; similar behaviour has been reported among Maguari Storks

Table 4: Frequency of trips for nest materials made by male and female Black-necked Stork during the breeding season

Month	Nest materials			Sex	
	Wet grass**	Dry grass	Others*	M	F
October 1996	3	17	10	20	10
November 1996	4	65	22	27	64
December 1996	7	21	1	3	26
January 1997#	-	4	1	2	3

** = Dry grass soaked in dew/water
* = Dried twigs, polythene papers
# = Parents stopped collecting nest materials on January 6, 1997. Juveniles left the nest for the first time on January 10, 1997.

in Venezuela (Thomas 1986). Both the storks were rarely seen arranging the nest materials together. On the contrary, in Little Blue Herons (*Florida caerulea*) the nesting materials were gathered exclusively by the male and were given to the female who arranged the sticks in the nest (Werschkul 1982). Every year with permission of the Forest Department, local villagers cut grass for thatching after which the uncut grasses were burnt. We observed that these activities did not affect the breeding storks adversely, except for forcing adult birds to skulk in the nest for a while until all the people had left the area.

Green veins of *Telliacora acuminata* (which are not very leafy) were used mainly to secure loose sticks. In the early stages of nest building we could not see what material the adult birds brought in for nest insulation. Throughout the breeding season, the ambient temperature remained below 15°C, especially in the morning till 1100 hrs. BNS therefore used readily available dried cut grasses as nest insulation, to maintain the internal temperature. Studies on the insulation properties of Wood Stork (*Mycteria americana*) nests indicate that clean nests could maintain the surface temperature of eggs/nest only 1.5-2.5°C above the ambient temperature during evening hours (Rodgers *et al.* 1988). Three experimental nests of Wood Stork in the United States with greenery exhibited higher insulation properties, especially in the intact and dried greenery nests (Rodgers *et al.* 1988), irrespective of the time of the day. This was contradictory to BNS in Dudhwa, which mostly used dry grasses. But often we had seen storks collecting dried, but water-soaked grasses from nearby during the sunny part of the day. This behaviour was observed on October 1, 1996; we presume that the female stork might have laid the eggs either on that day or within the next two days.

According to Rodgers hypothesis, a nest with fresh greenery had higher insulation value especially during the early morning hours. This may be due to the initial higher water content of the fresh greenery and resultant greater heat transfer through evaporation. The energy cost in procuring greenery was more than that of collecting dried grasses for BNS. Furthermore, the dried and cut grasses were available abundantly and close to the nest. Nest insulation depends on the materials used in nest construction, which depends on availability (Whittow and Berger 1977; Skowron and Kern 1980; Rodgers *et al.* 1988). Since BNS is a big (*c.* 6 kg) bird and cannot lift off suddenly with a huge load of greenery, to reach the nest situated on top of a 20 m high tree, it probably preferred dried grasses that have less weight. Similar preference for dry over fresh vegetation has also been reported among Great Tit (*Parus major*) (Mertens 1977). The availability and preference in terms of nest materials' usefulness determined the selection of nest insulation materials among BNS in Dudhwa National Park.

Table 5: Number of nest material trips made by parent Black-necked Storks

Month	Time of day (hrs)					
	0600-0800	0800-1000	1000-1200	1200-1400	1400-1600	1600-1800
October 1996	1	14	6	0	3	0
November 1996	14	40	4	0	5	25
December 1996	0	17	2	0	0	17
January 1997	0	2	1	0	0	4

Watering and nest material trips may have been combined with food trips to reduce the energy loss when storks go for such trips separately. By combining such trips, BNS also stayed with the juveniles longer, to give them protection. Trees are scarce and isolated in the grasslands of DNP, and thus the visibility was good for adult BNS. This probably helped the birds to detect and avoid predators. On two occasions, the BNS pair was seen chasing away the intruder (intraspecies) with great determination, even leaving the nest with eggs alone for a few minutes. Black-necked Storks are more aggressive towards intraspecifics during the breeding season, mainly (1) To protect the nest for the future, as BNS tend to use the nest year after year. If another stork identifies the nest, it may come and occupy the same in the next season. (2) As BNS prefers to build nests close to a good food source, it is possible that by identifying the nest of BNS, other birds with similar food preferences can exploit the food sources.

Approximately two days after the chicks had hatched, we saw the male BNS feeding on fish taken from the nest floor. One of the parents must have deposited these fish during the night. It appeared that, immediately after egg hatching, the adults start bringing food to the juveniles in spite of them being very young and not able to consume all the food.

Both male and female storks spend almost equal amount of time in feeding their young ones throughout the breeding season, but the amount varies. It was observed among Intermediate Egrets (*Mesophoyx intermedia*) that the number of feeding visits to the nest and the amount of food boluses regurgitated were in direct proportion to the number of chicks being fed (McKilligan 1990). The quantity and size of food brought by parent storks depended greatly on the age of their nestlings, as Kahl (1964) has reported in Wood Storks. Even though there was not much difference between the time spent by the male and female BNS for feeding the chicks, the frequency of feeding bouts varied significantly. This was

further evident from the change in the feeding bouts during the different chick stages. This difference might largely be due to the feeding success of the foraging BNS (Maheswaran and Rahmani 2002) in Dudhwa National Park. Among BNS, males were more successful in procuring food than the females. During the breeding season, the male BNS explored more wetlands situated in far off places than the female, and this was confirmed when the male was observed going very far from the nest and returning very late, sometimes 6-7 hours later. But, we did not observe the adult storks' foraging behaviour during breeding season. The female may have re-ingested less food during mid-day. This was due to the increase in consumption of food by the growing juveniles. The female fed the chicks with less food than the male; the regurgitated food was completely or mostly consumed by the juveniles. In the early stages, when chicks were not able to eat all the fish, the parents re-ingested it and offered it later in the form of a bolus. However, more studies on different nests either simultaneously or during different years are needed within Dudhwa.

Availability of food (Kahl 1964; Clark 1979) and ability of the parents to provide adequate food to their chicks (Coulter and Bryan 1995) affect the reproductive success of ciconiiform birds. In Dudhwa, immediately after monsoon (when water starts drying) all the ponds were full of fish, which supported all fish-eating birds including BNS (Maheswaran and Rahmani 2001). Some long-legged wading birds had the greatest reproductive success or began breeding in large numbers during years with faster drying rates than in years with slower drying rates (Kushlan *et al.* 1975). The male fled the nest and often stayed away from the nest longer to get enough food for himself, besides collecting food for juveniles. His tendency to feed the juveniles more than the female must have compelled the bird to stay away (foraging) from the nest for longer periods on a few occasions. The optimum level of parental investment can be determined by the reproductive value of the brood (Houston and Davies 1985; Moller 1986) and the survival chances of the parent and the young at the given level of parental effort (Chase 1980; Houston and Davies 1985; Sargent and Gross 1985; Winkler 1987). As a large wading bird, BNS requires considerable quantity of food, especially during the breeding season, for successful breeding. Low food intake is particularly critical for fish-eating birds because of their load of symbiotic gastric nematodes, which attack the host when food consumption is reduced (Kushlan 1974).

We found that the parental investment of the male and female BNS was not equal. According to Aguilera (1990), among White Spoonbills *Platalea leucorodia*, males generally were absent from the colony at night (presumably foraging), while females attended to the nests. Yet there may be differences in the optimal level of investment for each partner (Trivers 1972). Sometimes there appeared to be competition for food between the male and female on the nest, but the reason for which was not clear. During the chick-rearing period, the competition for food grew at the nest, and even hungry juveniles did not get enough food.

The main reason for juveniles not getting enough food even when the parents were present on the nest could be the adult's unwillingness to offer food, fearing that the other partner would pilfer it. Only on a few occasions (n=12) did juveniles get food when both parent birds were present at the nest. When the chicks became older and started consuming more food, responsibility of parents to find food increased and this led to the competition between them. The ravenous juveniles had to stay on the nest for hours together without food. Further study is needed to determine if this observed tendency of storks could be one of the reasons for the declining population throughout their distributional ranges, apart from habitat alteration. Reductions in potential habitats leave storks with less food, resulting in severe competition among the adults, sometimes forcing them to avoid breeding. In three years we could see only one pair (out of three) breeding within Dudhwa National Park, that too only in 1996. Why the other two pairs did not breed within the Park can only be clarified by carrying out detailed long-term studies.

ACKNOWLEDGEMENTS

We would like to thank the Ministry of Environment and Forests, Government of India and the Uttar Pradesh State Forest Department for their co-operation and support throughout the study. We are grateful to the U.S. Fish and Wildlife Service for financial support and guidance. We would like to thank Dr. Malcolm C. Coulter, Co-chair, IUCN/BirdLife International/Wetlands International, Specialist Group on Storks, Ibises and Spoonbills for help in the field as well as while GM was writing his Ph.D thesis. GM is grateful to Mr. Rupak De, IFS, Director, Dudhwa National Park for support and hospitality. GM is grateful to his field assistant Mr. Radhey Shyam for his commendable assistance in the field.

REFERENCES

AGUILERA, E. (1990): Sexual differences in nest attendance and chick-feeding rhythms of White Spoonbills. *Auk 107*: 416-420.

BAKER, J.R. (1938): The relation between latitude and breeding seasons in birds. *Proc. Zool. Soc. London. 108*: 557-582.

BURGER, J. (1978): The pattern and mechanism of nesting in mixed species heronries. Pp. 45-68. *In*: Wading birds (Eds: Sprunt, A. IV, J.C. Ogden and S. Winckler). *Natl. Audubon Soc. Res. Dep.*, Rep No. 7.

CHASE, I.D. (1980): Cooperative and non-cooperative behaviour in animals. *Am. Nat. 115*: 827-857.

CLARK, E.S. (1979): Factors affecting the initiation and success of nesting in an east-central Florida Wood Stork colony. *Proc. Colon. Waterbird Group 2*: 178-188.

COULTER, M.C. & A.L. BRYAN (1995): Factors affecting reproductive success of Wood Stork (*Mycteria americana*) in east-central Georgia. *Auk 112*: 237-243.

DORFMAN, E.J., A. LAMONT & D.C.R. DICKMAN (2001): Foraging behaviour and success of Black-necked Storks (*Ephippiorhynchus asiaticus*) in Australia: implications for management. *Emu 101*: 145-149.

HANCOCK, J. A. & J.A. KUSHLAN (1984): The Herons Handbook. Croom Helm, London, and Harper & Row, New York.

HANCOCK, J. A. & J.A. KUSHLAN & M. P. KAHL (1992): Storks, Ibises and Spoonbills of the world. Academic Press, New York.

HOUSTON, A. I. & N. B. DAVIES (1985): The evolution of cooperation and life history in the Duuock, *Prunella modularis*. Pp. 471-487. *In*: Behavioural ecology: the ecological consequences of adaptive behaviour (Eds: Sibly R. and R. Smith). Blackwell, Oxford.

KAHL, M.P. (1964): Food ecology of the Wood Stork (*Mycteria americana*) in Florida. *Ecol. Monogr. 34*: 97-117.

KAHL, M.P. (1971): Observations on the breeding of Storks in India and Ceylon. *J. Bombay. Nat. Hist. Soc. 67*: 453-461.

KAHL, M.P. (1973): Comparative ethology of the Ciconiidae. Part 6. The Black-necked, Saddlebill, and Jabiru storks (Genera *Xenorhynchus*, *Ephippiorhynchus* and *Jabiru*). *Condor 75*: 17-27.

KAHN, M.A.R. (1987): Conservation of storks and other waterbirds in Bangladesh. *Colonial Waterbirds 10*: 229-235.

KUSHLAN, J.A. (1974): Effects of a natural fish kill on the water quality, plankton and fish population of a pond in the Big Cypress Swamp. Florida Trans. *Am. Fish. Soc. 2*: 235-243.

KUSHLAN, J.A., J.C. OGDEN & A.L. HIGER (1975): Relation of water level and fish availability to Wood Stork reproduction in the southern Everglades, Florida. U.S. Geol. Survey. Open File Report 75-434. Tallahassee, Florida.

MAHESWARAN, G. (1998): Ecology and behaviour of the Black-necked Stork *Ephippiorhynchus asiaticus* in Dudhwa National Park, Uttar Pradesh, India. Unpublished Ph.D. thesis. Aligarh Muslim University, Aligarh, India.

MAHESWARAN, G. & A.R. RAHMANI (2001): Effects of water level changes and wading bird abundance on the foraging behaviour of black-necked stork *Ephippiorhynchus asiaticus* in Dudhwa National Park, India. *J. Biosci. 26*: 373-382.

MAHESWARAN, G. & A.R. RAHMANI (2002): Foraging behaviour and feeding success of the Black-necked Stork *Ephippiorhynchus asiaticus* in Dudhwa National Park, Uttar Pradesh, India. *J. Zool. (Lond.). 258*: 189-195.

MAHESWARAN, G., A.R. RAHMANI & M.C. COULTER (2004): Recent records of Black-necked Stork *Ephippiorhynchus asiaticus* in India. *Forktail 20*: 112-116.

MCKILLIGAN, N.G. (1990): The breeding biology of the Intermediate Egret Part 1: The physical and behavioural development of the chick, with special reference to sibling aggression and food intake. *Corella 14*: 162-169.

MERTENS, J.A.L. (1977): Thermal conditions for successful breeding in Great Tits (*Parus major*) II. Thermal properties of nest and nest boxes and their implication for the range of temperature tolerance of Great Tit broods. *Oecologia 28*: 31-56.

MOLLER, A.P. (1986): Mating systems among European passerines: a review. *Ibis 128*: 234-250.

NORUSIS, S. (1994): SPSS Inc. 444 North Michigan Avenue, Chicago, IL 60611.

RAHMANI, A.R. (1989): Status of the Black-necked Stork *Ephippiorhynchus asiaticus* in the Indian subcontinent. *Forktail 5*: 99-110.

RODGERS, A. W. & H. S. PANWAR (1988): Planning a Protected Area Network in India. Vol. 1 - The Report. Wildlife Institute of India.

RODGERS, J.A., A.S. WENNER & S.T. SCHWIKERT (1988): The use and function of green nest material by Wood Storks. *Wilson. Bull. 100*: 411-423.

SARGENT, R.C. & M.R. GROSS (1985): Parental investment decision rules and the concorde fallacy. *Behav. Ecol. Sociobiol. 17*: 43-45.

SKOWRON, C. & M. KERN (1980): The insulation in nests of selected North American songbirds. *Auk 97*: 816-824.

STATACORP. (1997): Stata Statistical Software: Release 5.0 College Station, TX: Stata Corporation.

SUNDAR, K.S. (2003): Notes on the breeding biology of the Black-necked Stork *Ephippiorhynchus asiaticus* in Etawah and Mainpuri districts, Uttar Pradesh, India. Forktail *19*: 15-20.

THOMAS, B.T. (1986): The behaviour and breeding of adult Maguari Storks. *Condor 88*: 26-34.

TRIVERS, R.L. (1972): Parental investment and sexual selection. Pp. 136-179. *In*: Sexual selection and the descent of man, 1871-1971. (Ed: Campbell, B.). Aldine-Atherton, Chicago.

WERSCHKUL, D.F. (1982): Nesting ecology of the Little Blue Heron: Promiscuous behaviour. *Condor 84*: 381-384.

WHITTOW, G.C. & A.J. BERGER (1977): Heat loss from the nest of the Hawaiian Honeycreeper "Amakihi". *Wilson. Bull. 89*: 480-483.

WINKLER, D.W. (1987): A general model for parental care. *Am. Nat. 130*: 526-543.

■ ■ ■